DOCUMENT RESUME

ED 265 405 CE 043 439

AUTHOR DeVore, Paul W.
TITLE Work and Programmable Automation.
PUB DATE 8 Apr 83
NOTE 22p.; Paper presented at the Annual Spring Conference of the Industrial Relations Research Association, West Virginia Chapter (Charleston, WV, April 8, 1983).
PUB TYPE Viewpoints (120) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Automation; Career Education; Computer Oriented Programs; *Employment Patterns; Employment Projections; *Futures (of Society); *Microcomputers; Robotics; *Role of Education; Technological Advancement

ABSTRACT

A new industrial era based on electronics and the microprocessor has arrived, an era that is being called intelligent automation. Intelligent automation, in the form of robots, replaces workers, and the new products, using microelectronic devices, require significantly less labor to produce than the goods they replace. The microprocessor thus makes it possible to have economic growth without increasing employment. Microprocessors and robots have altered and will continue to alter significantly the nature and character of work. If work is to serve human beings in their personal development, it seems imperative that they control the nature and character of their technical means so they contribute to, rather than detract from, the human quality of life. The institution of education has a responsibility to help people know and understand more about technical means and the relation of these means to social purpose, themselves, their work, the environment, and their future. The development of the microprocessor and other technical means forces a reassessment of traditional, institutionalized approaches. Education must focus on the future, learning how to learn, lifelong learning, and the skills associated with these processes which enable humans to reprogram themselves to do what they have not been trained to do. (YLB)

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ED265405

Work and Programmable Automation

A paper presented

by

Paul W. DeVore

at the

Annual Spring Conference

of the

Industrial Relations Research Association

West Virginia Chapter

April 8, 1983

Charleston, West Virginia

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Programmable Automation and Work

In a few years we will enter the 21st century. On the way we will experience many changes. Many believe these will be the most significant changes in the history of civilization, as important as the heat engine and the factory system.

We are entering a new era, an era that is being called intelligent automation. Some believe the era will be a new industrial revolution, a revolution most of us are not well prepared for and one that will affect each of us in one very critical aspect of our lives, our work.

How can we be so sure significant changes will take place? There are a number of indicators. Truly significant changes in human potential and the order of things seem to come about with the creation of either: (1) a more stable food supply; (2) new and better materials; (3) alternative forms of energy supply; and/or a more efficient means of energy conversion; (4) a more efficient means to collect, store, transmit and process information; or (5) a better means to control tools, machines, and technical systems.

The lateen sail is an example of one of the earliest and more significant technical developments relating to control. It enabled mariners to control their boats and sail against the wind. The lateen sail, the stern post rudder and the magnetic compass, together with information about the stars, provided the technical means and information necessary to circumnavigate the globe and engage in regularly scheduled commerce throughout the year.

Today new forms of energy and materials, information about the orbits

of the planets, and control (in the form of inertial navigation and the computer) have provided the means to reach the moon and the stars beyond, and, in the process, have changed our perceptions of who we are and what the future may bring. These and other technological developments have altered the reservoir of technical means from which our future will emerge.

This reservoir contains the means for the beginning of another major technological revolution. It is a revolution based on information and control and the significant component is the integrated circuit chip which has made possible the microprocessor--a computer-on-a-chip. In 1982 over 2.8 million personal computers were sold for use in businesses, industry, schools and offices. The predictions are that continued development of microelectronics and their offspring, microprocessors, will bring about changes in every aspect of societies throughout the world.

A New Industrial Era

Even though the new industrial revolution, based on intelligent automation, has been ongoing for several decades, many people still believe that the largest employment sector in the United States is manufacturing, commerce and industry. This was so in 1920 when 53% of the workforce was employed in these sectors, but not today. There has been a major shift. The United States has evolved from a preindustrial society, where large amounts of physical labor were employed to grow food and to extract the raw materials from the earth, to an industrial society where new forms of energy and energy conversion were used to drive machines operated by semi-skilled workers to turn raw materials into products that created a

technical environment. Today, a new form of society is emerging, a post-industrial society based on knowledge and information. Fewer than 29% of the workforce in the U.S. are engaged in manufacturing today. It is predicted that by the year 2000 the amount will be 22% or less.

The major change has been toward jobs and employment in the knowledge and information sectors. About half of all people employed in the United States today are in jobs related to knowledge and information generation, transmission, storage, retrieval and use. A new economic and employment base has evolved, one based on information rather than on the physical production of goods.

The new industrial era is based on electronics and the microprocessor or computer-on-a-chip, the foundational development that provided the turning point toward a new era.

The Information Revolution

In the 1950s there were some 1000 or so computers, but no microcomputers (or microprocessors). In the late 1970s there were over 220,000 computers and some 750,000 microprocessors. During the 1980s the number of microprocessors will exceed 10 million and usher in a new technological revolution that, from all predictions will have a greater and more profound impact on societies throughout the world than did the industrial revolution.

All aspects of living are being affected directly or indirectly; education, the home, agriculture, transportation, recreation and medicine. New uses and applications are being developed every day. Microprocessors provide the means for control of all forms of industrial and business

operations providing what has been called intelligent automation. Microprocessors are used in oil refineries, chemical plants, paper mills, steel mills, power stations, research laboratories, offices, and homes. They are being used to control internal combustion engines to improve fuel economy and lessen pollution. The range of applications is staggering.

The development of the microprocessor came about in 1969 when an engineer for Intel Corporation, M.E. Hoff, was searching for a better way to produce silicon chips for use in electronic calculators. He found it was possible to incorporate the entire central processing unit (CPU) of a computer onto a single silicon chip. Combining the microprocessor with additional chips to provide other functions such as memory, Hoff created a micro-sized computer. By 1980 his creation had evolved to where a pocket computer selling for less than $250 had computational powers comparable to ENIAC (the first electronic computer) and considerably more memory. ENIAC had 18,000 vacuum tubes, occupied a large sized laboratory room and weighted over one ton, and was far less reliable.

Another critical turning point, which enabled the large scale application of microprocessors, was the development of the means to manufacture a silicon chip with tens of thousands of electronic components and complex circuits imprinted on it.

Silicon chips are about one-fourth the size of a standard postage stamp. This breakthrough reduced the size of electronic equipment and increased the power and flexibility of small computers, while at the same time reducing costs on the order of 100,000-fold.

The construction and design of integrated circuits, the core of microelectronics, have improved so that greater numbers of transistors, resistors, diodes and other electronic components can be placed on a single silicon chip. In 1971, Intel, Inc., following the work of their engineer, M.E. Hoff, brought out the microprocessor by putting the entire central processing unit of a computer on a chip. By 1980 the power and the capability of the microprocessor were increased by new manufacturing capability enabling the placement of 200,000 components on a single chip. The Japanese have chips in development that will contain 250,000 circuits. By 1985, manufacturers predict integrated circuits will be available with one million components and by 1990 as many as 10 million transistors on a single chip.

Robotics

Intelligent automation, a step beyond electro, hydraulic, mechanical automation, is possible today because of the computer-on-a-chip, the microprocessor. The most pervasive development with the greatest direct impact on workers is in the use of robots, controlled by microprocessors, on the assembly line. The microprocessor provides the programmable information and control functions that enable the design and operation of entire manufacturing plants by robots which perform the same functions as humans but in most cases better.

Robots are not new. There have always been attempts to design machines to do the work of humans. As knowledge of gears, levers, cams and various control devices became more sophisticated so too have the sophistication of the machines used in manufacturing. Many early robots were toys

ranging from the highly automated clocks of the middle ages to mechanical birds and music boxes with dancers on the top.

The word "robot" came into use in the early 1920s after the Czech playwright Karel Capek, created the play R.V.R. (Rossum's Universal Robots). The play depicted a society where robots freed humans from labor but later attempted to take control.

In all the early efforts in automation there was a problem, the size of production. Until the advent of the microprocessor, automation had been restricted to high volume production because of the cost of designing and constructing the many specialized machines. The microprocessor has changed this. The microprocessor makes it possible to develop reprogrammable machines--robots--that make it economical to automate plants that heretofore had production runs that were too small to justify the cost of automation. Most manufacturing throughout the world is in this category, meaning that major changes, for the first time since the advent of the assembly line, will take place in the way goods are produced and plants are organized. Time magazine reported in December 1980 that 60 percent of U.S. manufacturing is done in batches too small for assembly lines and that robots can be programmed to do these jobs and reduce costs in small-lot manufacturing by 80 percent to 90 percent. An important advantage is that the brain of the robot, the microprocessor, can be reprogrammed in a few minutes.

One major effect of this technological advance on workers will be a significant reduction in the number of people required to produce a product. For example, at the Matsushita Color TV plant near Osaka, Japan, 80 percent of the parts for color TV sets are put in place by robots.

Furthermore, the use of robots reduced the rejection rate from 5 percent to a small fraction of 1 percent.

Industrial robots are being used world wide. The leader is Japan which has become the world leader in automobile production and sales largely because of the extensive use of robots in the manufacturing process. Robots have enabled Japan to reduce labor costs, improve quality and increase production. Japan plans to increase productivity by 70 percent during this decade through the use of robots.

As of now robots cannot compete with traditional automation composed of specialized tools performing repetitive, non-variable, high volume work. Nor can robots compete in precision assembly at their current stage of development. With the coupling of programmable manipulators to artificial intelligence related to visual and tactile sensing and pattern recognition, the stage will be set for the adoption of robots in a wide range of jobs currently performed by humans.

Tomorrow's Jobs

No technical development in history, including the computer, has had the potential of altering jobs and employment worldwide as has the development of microelectronics and the microprocessor. Not only will jobs be eliminated through intelligent automation, but many jobs will be lost in the manufacture of electronic products because they contain fewer parts than the products they replace. For example, the National Cash Register Company switched from the manufacture of mechanical and electromechanical cash registers to electronic cash registers and in the process reduced its workforce 25 percent.

Historically, our experience has been that the adoption of a new

invention or innovation into society created new potential and thus new jobs. Yet, the microprocessor seems to be different in several important ways. The microprocessor appears to be all-pervasive. No business, industry or occupation will be untouched. In addition, the microprocessor will have an impact not only on the numbers of jobs but also on the structure of the work available. But perhaps most important of all, the microprocessor makes it possible to have economic growth without increasing employment. Norman ([b], p. 31) reports that this occurs for two reasons. Intelligent automation, in the form of robots, replaces workers, and the new products, using microelectronic devices, require significantly less labor to produce than the goods they replace, primarily because fewer parts are involved. By way of example, an electric telex machine manufactured by Standard Electronic Lorenz of West Germany used one microprocessor to replace 936 moving parts. The General Motors plant in Lordstown, Ohio, increased production by 20 percent while reducing the workforce by 10 percent (Norman [b], p. 33).

The impact on jobs has been significant in many industries. Studies reported by Norman [a] found that employment among printers dropped by 21.3 percent in West Germany between 1970 and 1977 while productivity rose 43.5 percent. Similarly, the Journal Bulletin in Providence, Rhode Island, decreased workers in the composing room from 242 in 1970 to 98 in 1978 to 54 in 1980. Other jobs that will be affected, according to a British study, are proofreaders, telegraph operators, draftspersons, accountants, secretaries, billing clerks, keypunchers, filing clerks, meter readers, telephone repairers, machinists, sales clerks and compositors,

among others. The labor intensive garment industry, a mainstay of developing countries, will be affected by a computerized system for laying out patterns on the material to be cut and an electronically controlled laser cutter. In one British plant using this process labor requirements were reduced from 200 to 20 people. Norman reported that the textile industry in the United States will spend about $2 billion a year during the 1980s on new equipment, some of which will be computer controlled. General Electric spent $5.1 million in 1980 for 47 robots for their appliance finishing operation. They saved $2.6 million in labor costs. The goal is to replace one-half their 37,000 assembly workers with robots. As many as 300,000 low-paying jobs could be eliminated in U.S. textile plants by 1990 and many more in other industries, causing serious social problems for those whose education and training have not prepared them for the limited number of more highly skilled jobs.

There will be new jobs in those industries manufacturing electronic products such as watches, calculators, TV games and home computers, but the loss of jobs will exceed the gain. It is interesting to note that there has been a significant increase in jobs in restaurants and fast food establishments since 1973. The number of new jobs exceeds the combined number of jobs in the automobile and steel industries. It is possible that more and more people will find that the new era will place more and more workers into low level non-career jobs.

Many of the jobs that exist today will exist in the future, but the number of jobs available, as well as the content of the jobs, will probably be altered significantly. Police officers, secretaries, truck drivers, accountants, chefs, appliance repairers, automobile mechanics

and electricians, among others will probably exist in the future. However, the demand for workers in various occupations will be altered by shifts in the population, the introduction of new technical means, and the development or adoption of new organization and management techniques influenced by the computer and microprocessor.

Tomorrow's Workers

Individuals are most directly affected in their work where the structure of the workforce is being upgraded with fewer jobs for unskilled workers and more skilled, technical and professional jobs. Technological changes being made today reduce the demand for manual dexterity, physical strength and traditional craftsmanship. Increasingly employers are emphasizing the need for formal knowledge, precision, and perceptual appitudes. The new technologies are not based on manual skill, but on knowledge, thus more education and higher education for workers is becoming essential. Narrow job training will no longer be prudent and, in fact, may be detrimental and in many ways inhuman. The ability to read and write is minimal and mandatory for interpreting instructions for the operation of more complex equipment and to participate sucessfully in in-plant retraining programs conducted by the industries as they adopt newer and more sophisticated equipment.

The major portion of tomorrow's production jobs will go to a new type of worker.

The industrial worker of the future in all probability will be "a reprogrammable, multifunctional manipulator designed to move materials, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks." This is how the robot

Institute of America defines the industrial robot. The U.S. Robot industry, made up of companies such as Unimation, AMF Versatran, and Cincinnati Milacron, is producing about 1500 units per year. The biggest producer is Japan, where Kawasaki, Hitachi, Mitsu and Mitsubishi produce five times more than the U.S. Time reports that Fujitso Fanuc opened a new plant in Japan in January 1981 where robots will work 24 hours a day to produce about 100 robots each month.

As the trend continues what will humans be doing? What will the future bring for the American worker? These are serious questions because work is central to our lives and gives meaning to our existence. To have it altered extensively or denied to us can bring about serious human problems.

Work and Its Importance to People

What we are as individuals, how we perceive ourselves and our importance in our family, in our neighborhood and in society is to a large extent determined by our work. And the nature and character of our work is determined by the nature and character of our technical means and how they are employed.

Work related to the technical means of the industrial era is standardized, specialized, synchronized, and centralized. In those work places where these characteristics exist, work for many has lost its meaning. Workers in these work environments became alienated from their work. Many studies of worker alienation have been made and the findings are known by most people concerned with work and labor. It is important to emphasize two critical discoveries, however. One was that paid employment and work

are not the same. Work is something you do that is beneficial to the welfare of another person whether you are paid or not. When your work does not contribute to the benefit of another and is not rewarding to you it is a job, but not work.

Work should be a positive element in one's life. It should contribute to the wholeness of one's life and not detract from it. Work should be a part of one's total life. Unfortunately, during the industrial era the creation and use of certain new forms of tools, machines and technical systems separated work from life space.

Work, for many, has been effectively separated, dissected and emptied of meaning; divorced from human expression. The quality of life has been degraded.

One way of determining whether one's work contributes to one's life or detracts from it is to apply the discontinuity test. The less discontinuity that exists between one's work life and the non-work life, the higher the quality of life. People whose work is closely integrated with their total life, their life space, are less alienated and more satisfied. They live a healthier, more productive life.

Satisfaction in one's work contributes significantly to one's emotional balance. Not only does work help satisfy a person's economic needs but also one's personal needs for companionship, affection, self esteem and the esteem of others. How will these critical elements be affected by the new intelligent automation which will alter significantly, not only the opportunity to work, but also, the nature of the work and what a worker does? Will the alienating factors of powerlessness, isolation, meaninglessness and self-estrangement be a part of most jobs in the future? Or

will the new jobs provide more meaning, more freedom and less alienation, as did the craft era which preceded industrialization and automation.

Is it possible that the microprocessor and robotics will reverse the trend of worker alienation by altering the content of work and return to the worker (i) the ability to control the work process, (ii) an opportunity to find a sense of purpose in work and its social setting, and (iii) a means to be involved in work that enhances self-expression and self-esteem? This has not been so in the past. Predictions are that the adoption of microprocessors will lead to more control over the work-force with more and more of the work reorganized around the dictates of the new technical means.

Humanizing the future is basically a question of humanizing work, and humanizing work is a question of designing technical systems that contribute to the humanizing process, something we know little about.

It is obvious that microprocessors and robots have altered and will continue to alter significantly the nature and character of work in the near and long term future. Full automation, using computer controlled robots, will eliminate most work as we traditionally perceive work. Thus, if work is to serve us in our personal development, it seems imperative that we control the nature and character of our technical means so they contribute to the human quality of life rather than detract from it. With respect to this point it is important to remember that a given form of tool or device does not determine, necessarily, how it will be used. It does not direct that work be performed a certain way. Working conditions, whether they relate to mechanical automation or programmable automation, are determined by economic and social objectives.

The task is formidable and places a major responsibility on the institution of education. Technological change today is widespread and extensive and for the most part those affected by it often cannot comprehend the nature of the new technical means nor the changes affecting them and society. They have neither the awareness nor a concern about social purpose, technology assessment or work and its meaning to themselves and others. In the meantime, the creative entrepreneural mind continues the technical evolution unchallenged.

Other Changes

Business and industry spend about $70 billion on research and development each year in the United States. Over 31,000 domestic patents were issued by the U.S. Patent Office in 1979. A recent patent, issued to Stanford University in 1980, may signify changes in our future way of living as great as the microprocessor or the establishment of the irrigation societies seven thousand years ago in Mesopotamia, Egypt, China and the Indus Valley. The patent was on basic gene-splicing techniques. Research is now under way to change the DNA molecule--the one that controls the direction of growth--in a strain of bacteria to create a strain that can synthesize oil compounds similar to the petroleum deposited around the world. The potential of oil being a renewable resource would alter the entire future of the world as presently conceived.

So will new approaches to the perception of life and living and the relation of human beings to their environment. The conservation ethic for instance, including the promotion of renewable resources and living with respect for the environment and the Earth's resources, would have a

tremendous effect on our lives, our work and the future.

Genetic research and the reexamination of our mission on earth will affect our future as much as microwave landing systems, satellite communication, electronic mail, electric automobiles and computer-controlled twin-wire paper machines capable of producing a mile of paper 234" wide every two minutes.

A Global Future

Even with all these new potentials and changes we must remind ourselves that our future is linked irreversibly to the rest of the world. More and more people of the world are dependent on each other, whether the context is the environment, raw materials, energy supply, finished products, food supply, or knowledge and know-how. The advent of television and communication satellites and the resulting rising expectations of people throughout the world, coupled with the microprocessor and its potential for accelerating the pace of technological change, portend a future far different from the present.

It is also a future that will be determined and structured by the nature and characteristics of technical systems. Thus, if we plan to control our future we need to know and understand more about technical means and the relation of these means to social purpose, ourselves, our work, the environment and our future. To do otherwise may result in our computers taking command because the mission is too important to be trusted to poorly educated and ill-prepared human beings--a decision that was made by Hal, the on-board computer of the space ship in the film 2001--A Space Odyssey.

What advice does one give to the young or those involved in educating our future generations? Change will be a constant, for we have institutionalized change. We invest in it and plan for it. How do we prepare people to be productive and contributing citizens, to earn a living, to find rewarding and satisfying work?

Typically, we have focused education on preparation for jobs and careers that already exist rather than focusing on the development of knowledge, skills and attitudes required for lifelong learning. The development of the microprocessor and other technical means forces a reassessment of traditional, institutionalized approaches.

Currently the content of education focuses almost exclusively on the past. Yet, it is the future, not the past, that is supposedly the mission of education. It is a future that is not fixed. It is a future that is in the process of becoming. It is a future that will be drastically different from today. Whether we act or not, choices will be made. It is a future where the actions, procedures and behaviors of today will not work any better than those of prior years do today. Certainly it would be a poor investment to prepare people for any job or career that can be taken over by a robot, or programmed on a microprocessor. Being literate and employable in the future may depend on one's ability to program and operate the hundreds of thousands of microcomputers that will be a part of business and industry, large and small. The pace of change will also place a premium on <u>learning how to learn</u> and lifelong learning and all the skills associated with these processes which enable humans to reprogram themselves to do what they have not been trained to do. Those who do not develop these basic and imperative skills will be

unemployable in the future. Many are now. They will also be incapable of contributing in a meaningful way to creating a meaningful future for all of us.

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